Utilizing Remote Sensing Indices to Evaluate Hydrologic Recovery in the Arroyo Seco Watershed

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2012 Southwest Wildfire Hydrology and Hazards Workshop
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Fire Studies at UCLA

2003 - Old Fire (San Bernardino Mts.)

2005 – Topanga (Malibu Canyon) and Pines Fire (Arroyo Seco)

2006 - Day Fire (Piru Creek-Pyramid Reservoir)

2009 – Station Fire (Angeles NF, Arroyo Seco)

2010 – Bull and Canyon Fires (Sequoia National Forest)

Water quality (stream, reservoirs, soils): Metals (mercury), nutrients, sediments

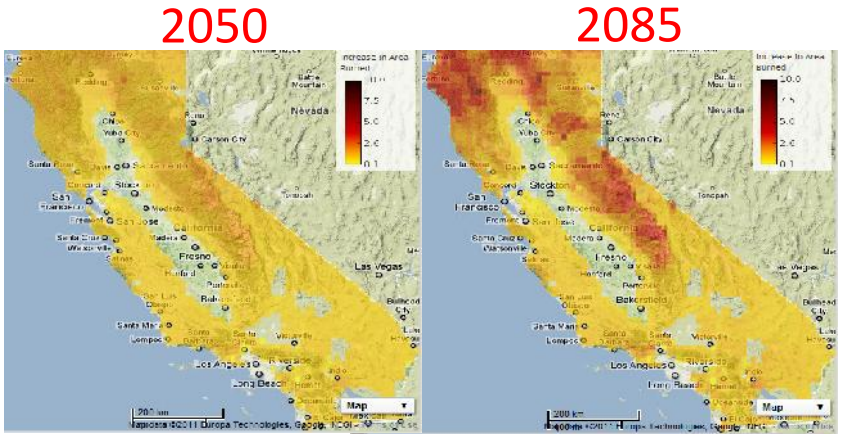
Vegetation recovery and coupled hydrologic response, water yield

Modeling post-fire processes – Flooding, water quality, sediment transport

Motivation

Issues

- Increasing wildfires at wildland-urban interface (WUI)
- Significant post-fire consequences
- Uncertainty in long-term hydrologic response



Cal-Adapt, 2011

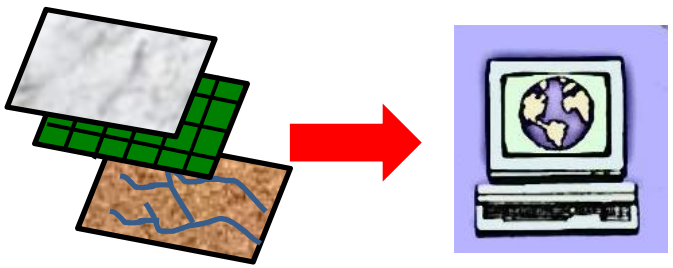
Methods

Apply remote sensing products to burned watersheds

I. Previous post-fire recovery work

II. Water and energy balance variables

- Evapotranspiration

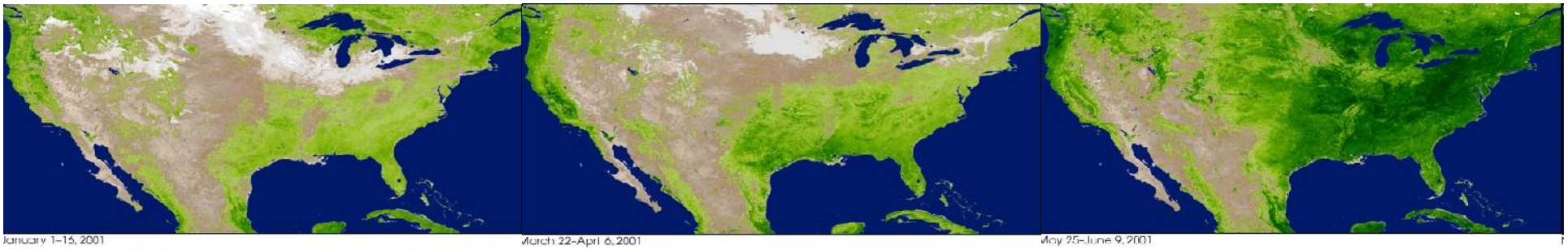


Goals

- Improve hydrologic estimations and recovery prediction, especially in ungauged/inaccessible areas
- Model development for post-fire prediction

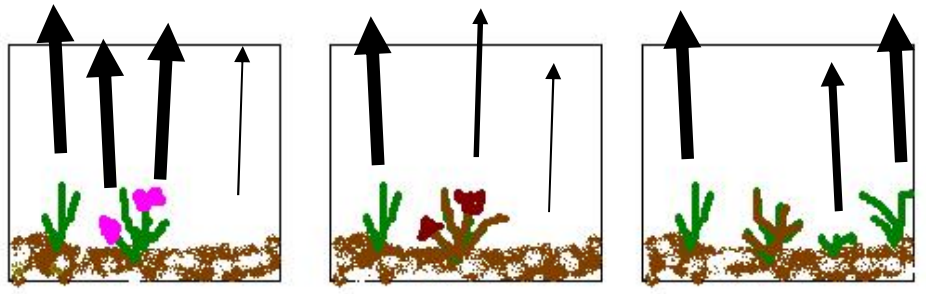
- Moderate Resolution Imaging Spectroradiometer (MODIS)
- Terra and Aqua Satellites
- Advantages: multiple spectral bands, daily overpass
- Disadvantage: Lower spatial resolution (250m)

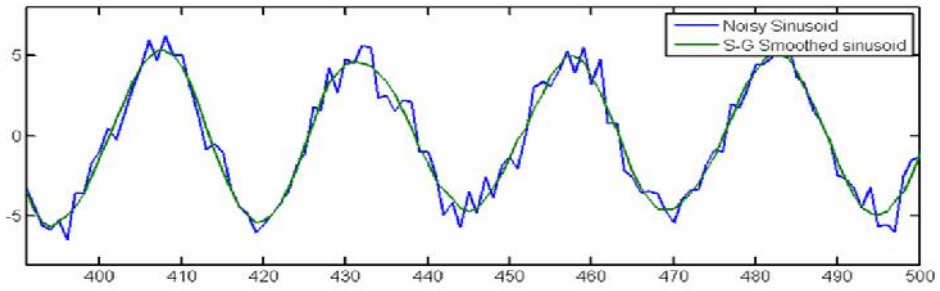
MODIS Terra Enhanced Vegetation Indices (EVI)



$$EVI = 2.5\left[\frac{\rho^*_{NIR} - \rho^*_{RED}}{\rho^*_{NIR} + C_1\rho^*_{NIR} - C_2\rho^*_{BLUE} + L}\right]$$

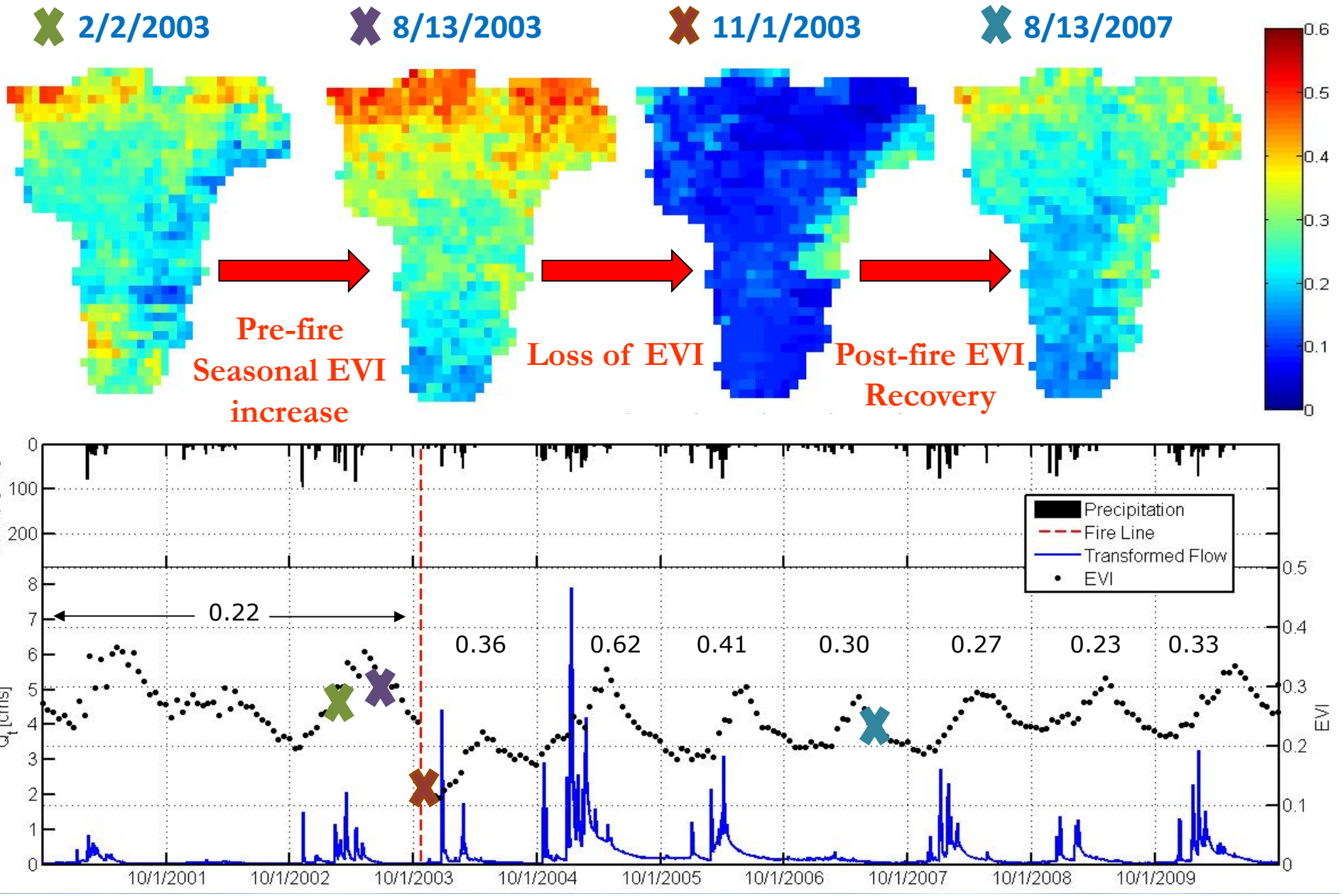
- Temp: 16 days
- Spatial: 250 m
- Spatial EVI patterns
- EVI statistical analysis
- Long-term time series





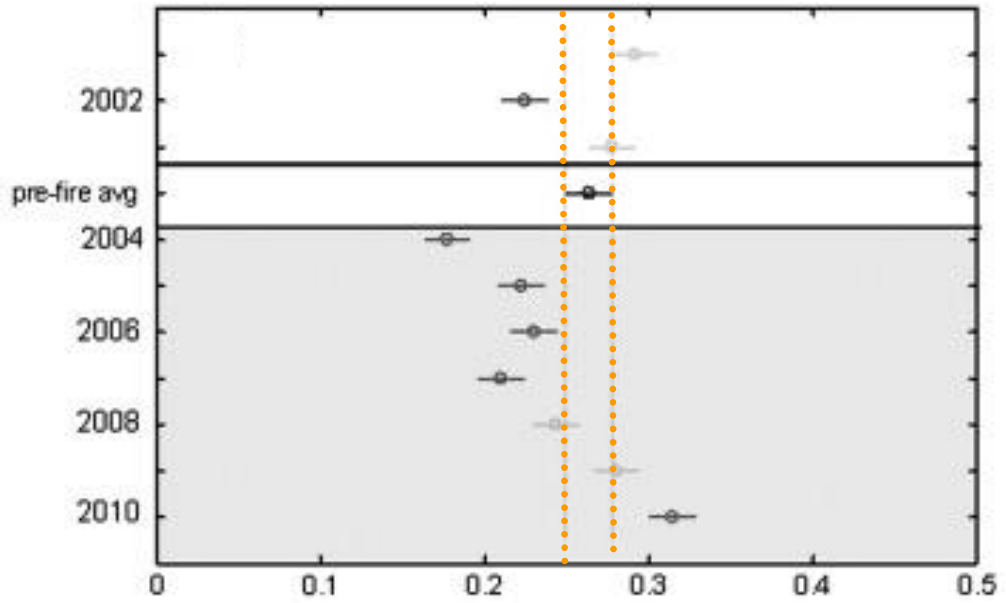
I. Previous study of hydrology and vegetation recovery

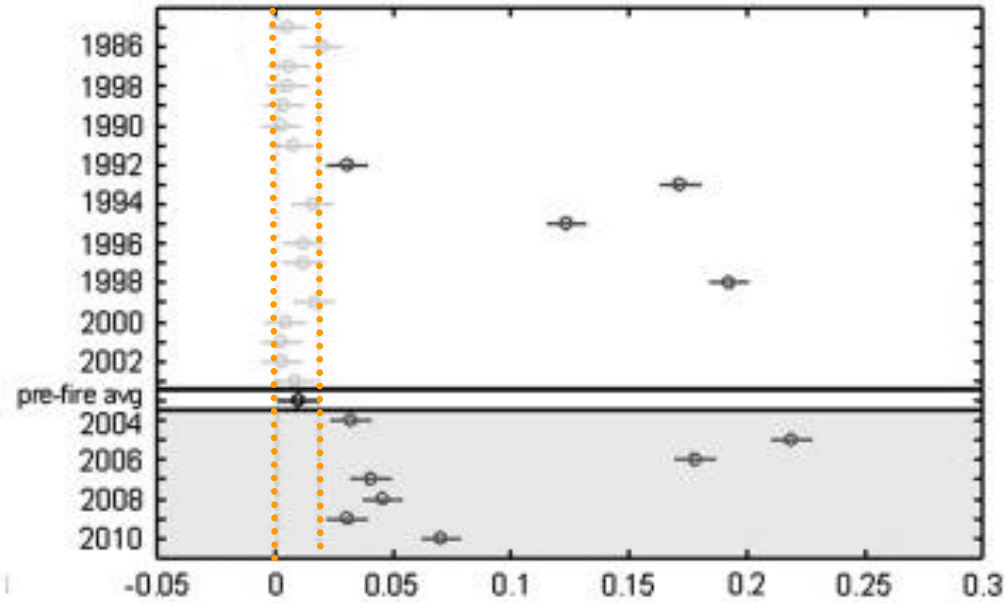
Kinoshita and Hogue, 2011



Discharge is not similar to pre-fire conditions…

Kinoshita and Hogue, 2011



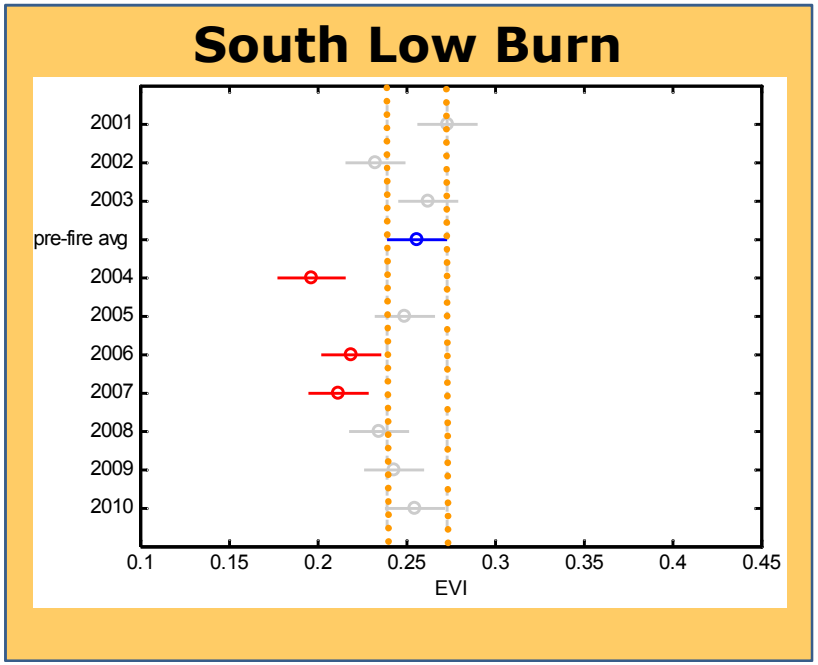


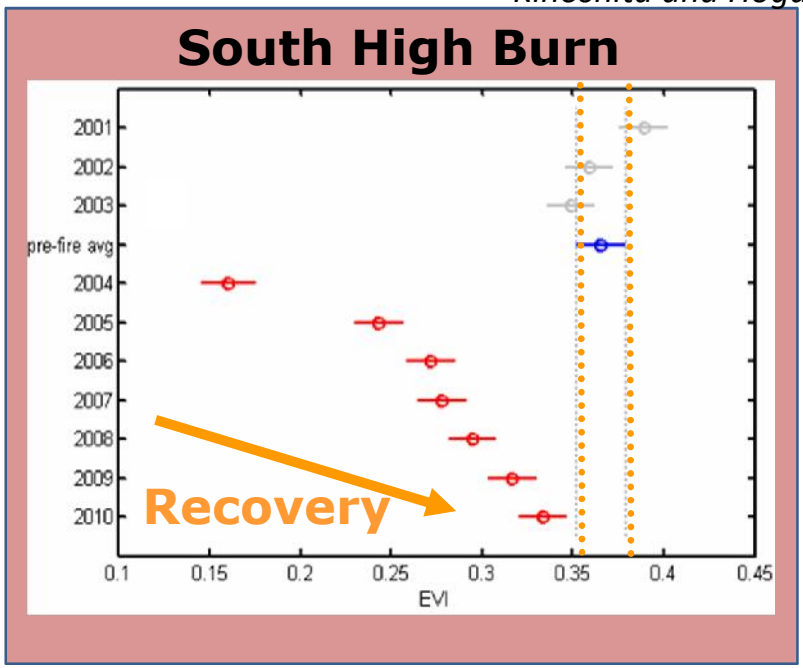
Annual basin average EVI
"recovers" by 2010

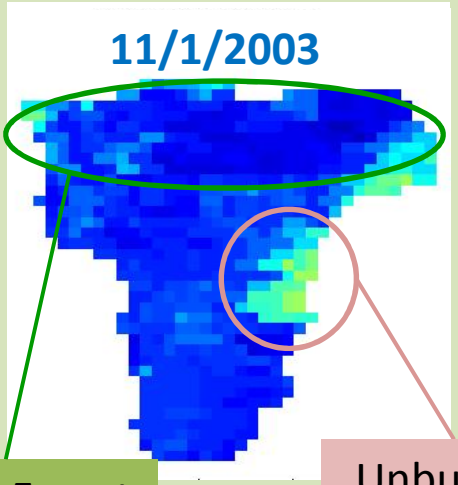
Annual discharge (cms)
- Pre-fire outliers – El Nino years
- Discharge not similar by 2010

Burn severity, aspect, and post-fire climate affect recovery

Kinoshita and Hogue, 2011





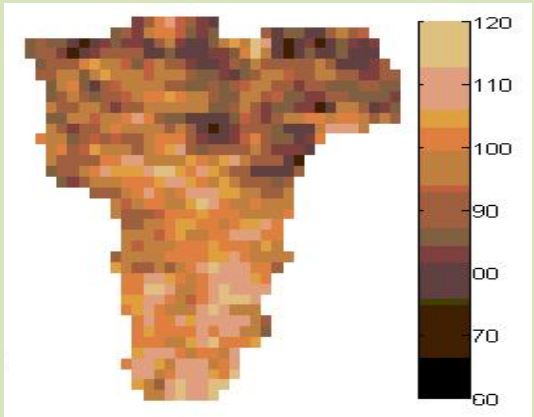


Mixed Forest

Unburned

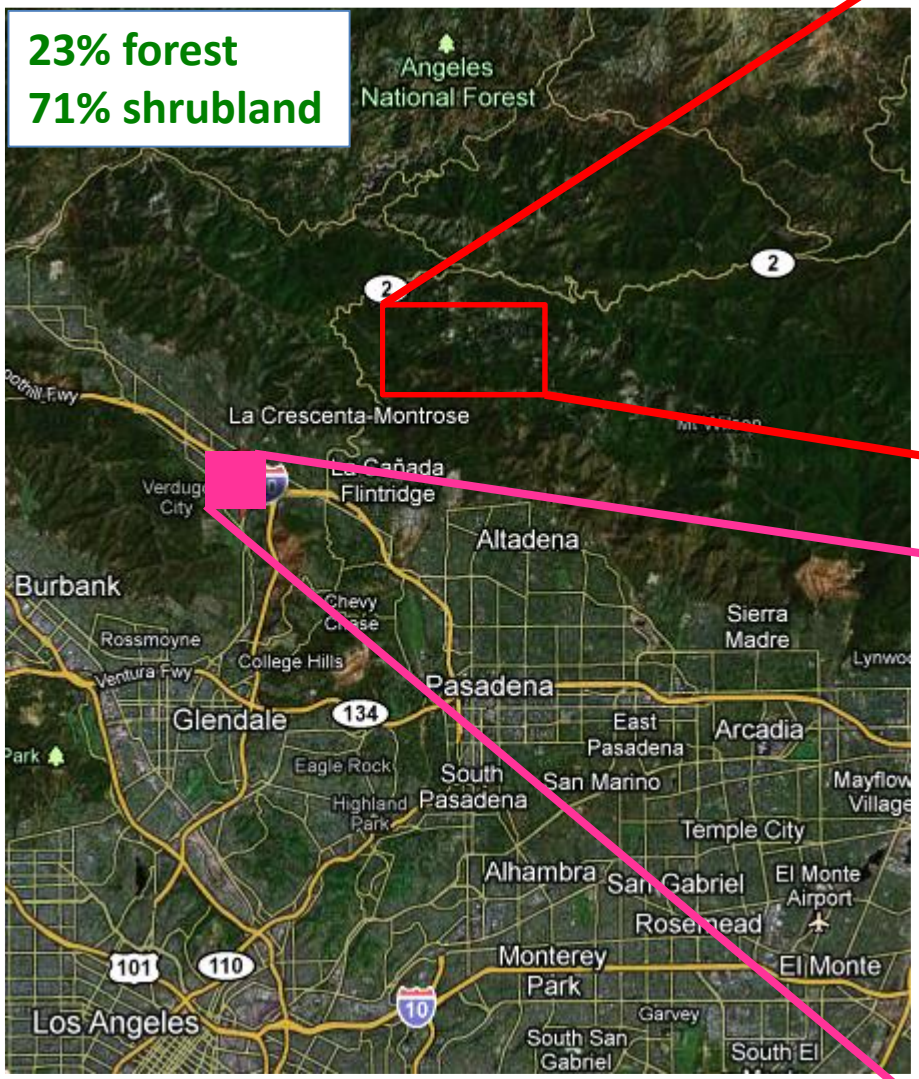
Annual EVI relative to EVI lost

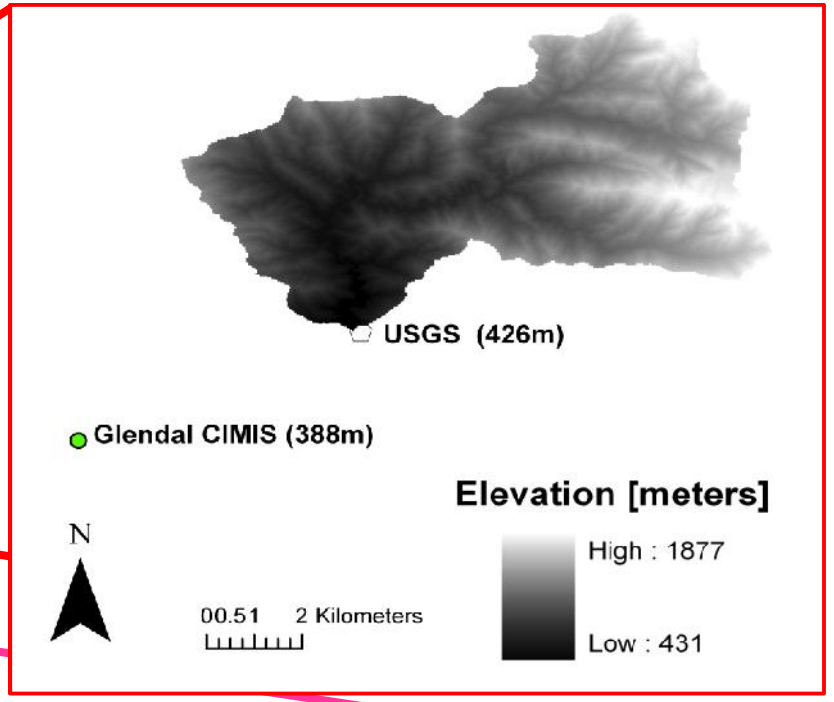
% Recovery 2007



% Recovery 2010

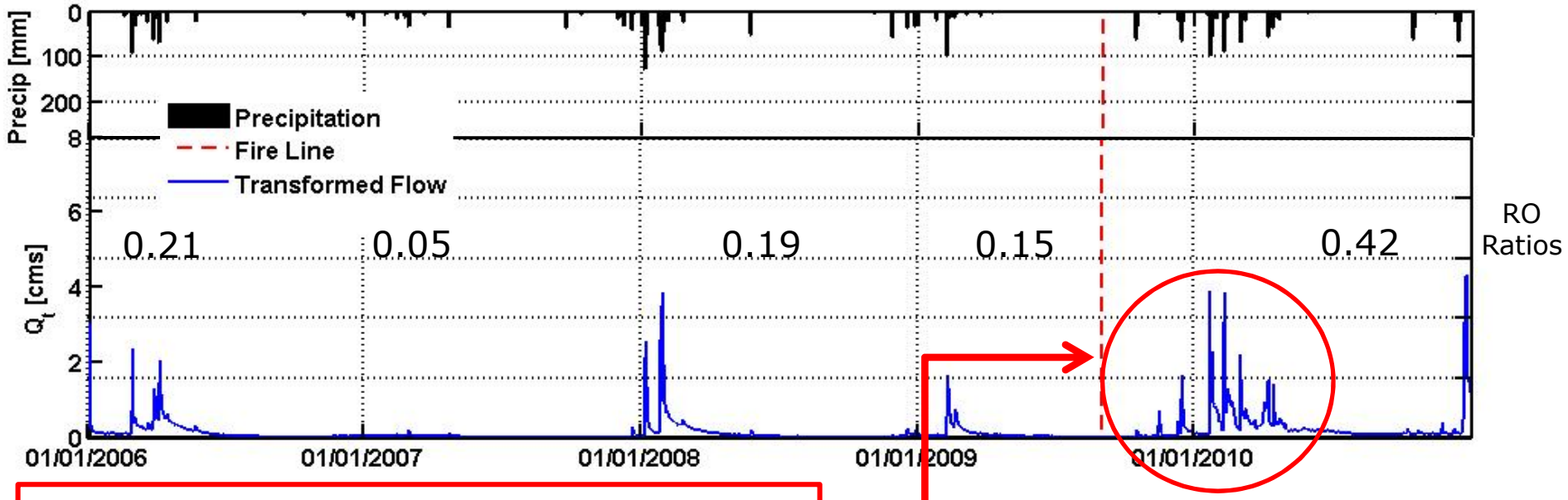
Current Work: Arroyo Seco (41 km^2), Angeles National Forest, California





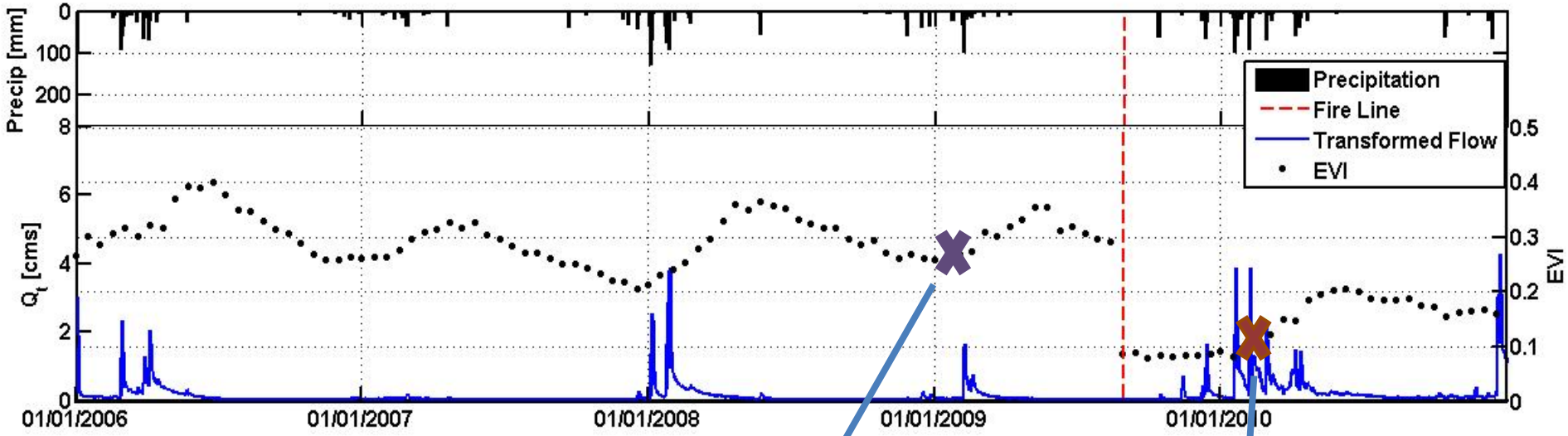
Glendale CIMIS weather station

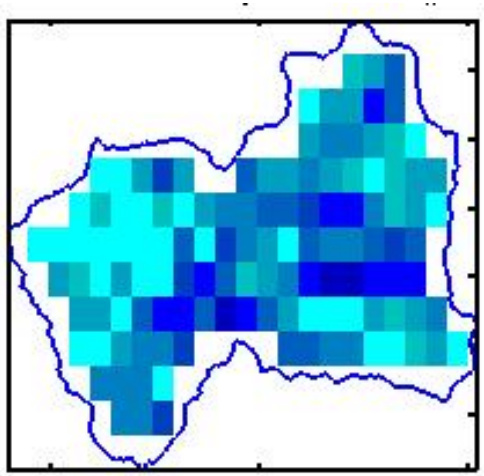
Arroyo Seco Hydrology

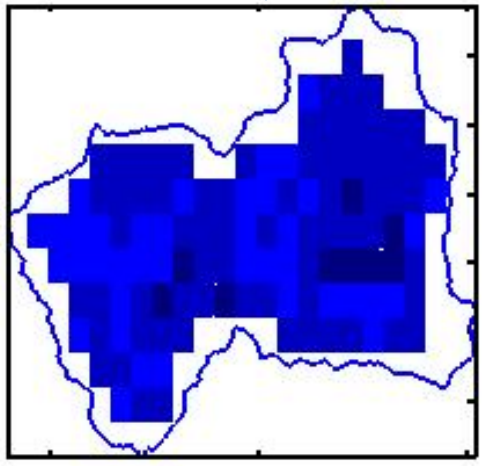


Arroyo Seco is 100% burned (~moderate severity) by the Station Fire (2009)

Arroyo Seco Hydrology and Vegetation Response (EVI)







January 17, 2009

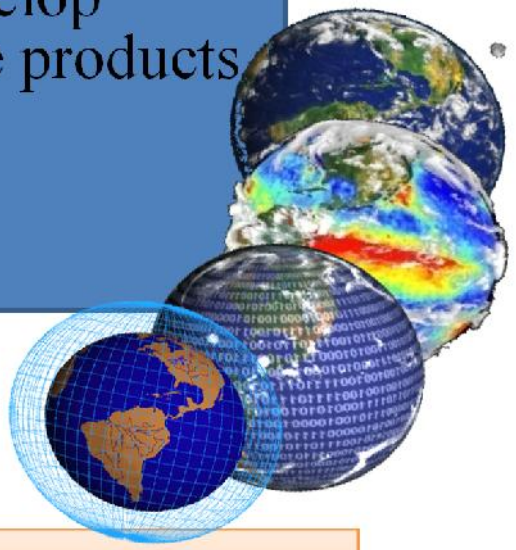
January 17, 2010

II. Satellite-based Products for Post-fire Water Budgets

(based on work by Kim and Hogue, 2008; 2012)

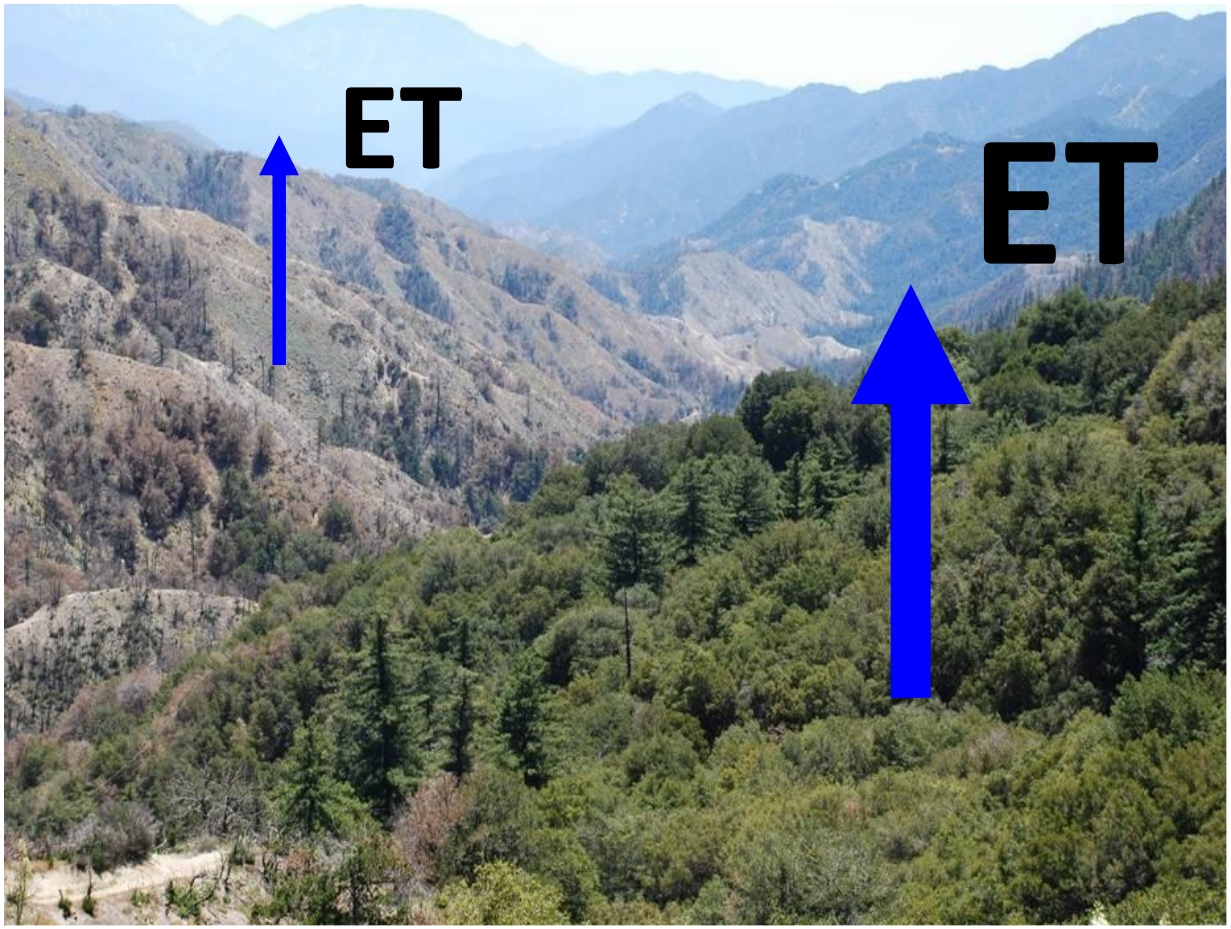
Approach: Build upon existing theory and develop remotely-sensed hydrologic and energy balance products for burned (ungauged) application

- Evapotranspiration (AET)
- Soil Moisture



Application: Land cover change assessment (fires, urbanization), model development, forcing, validation, regional water budgets, recovery, etc.

Key Alteration - Evaporation and Transpiration (ET) Processes



<u>UCLA ET Algorithms</u>

- Modified Triangle -
- Modified SEBAL

(Kim and Hogue, 2008; 2012)

Net Radiation Product $Rn = SW\downarrow - SW\uparrow + LW\downarrow - LW\uparrow$

Kim and Hogue, 2008

Net Radiation (250x250m, Daily)

Shortwave Radiation
- **MOD03** (1x1km)
  Solar Zenith Angle, Geolocation (Lat,Lon)
- **MOD04** (10x10km)
  Aerosol Optical Depth, Angstrom Exponent
- **MOD05** (1x1km) - Water Vapor
- **MOD43** (1x1km) - Albedo

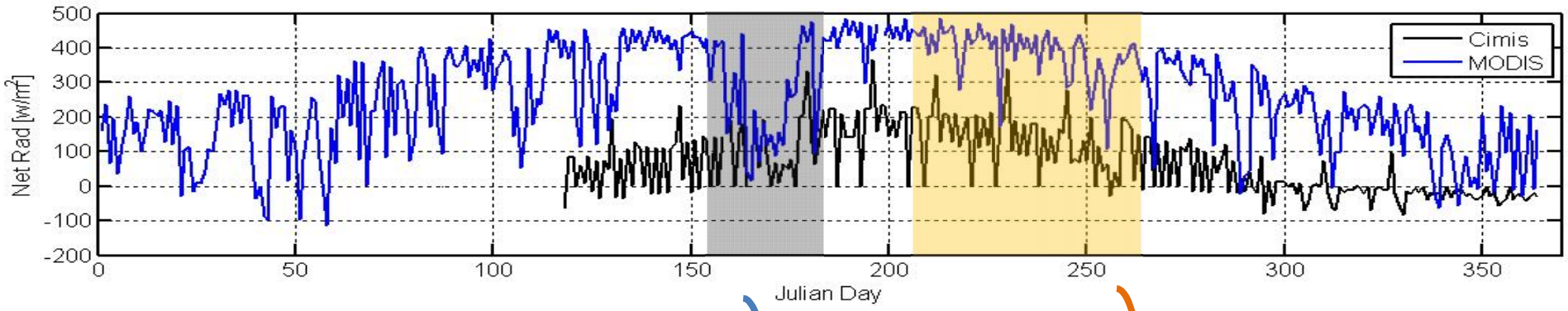
Longwave Radiation
- **MOD06** (5x5km)
  Total Ozone, Air/Dew Point Temp
- **MOD11** (1x1km)
  Emmisivity, Surface Temp

Ground Heat Flux
- **MOD13Q1 & MYD13Q1**
  (250x250km) EVI

$$G = f(Rn, NDVI)$$

Cloudy Condition
- **MOD06** (1x1km)
  Cloud Fraction, Cloud Optical Thickness, Surface Temp

Bisht and Bras, 2010; Kim and Hogue, 2011



CIMIS: 388 m

Range of Arroyo Seco: 431-1877 m

Actual Evapotranspiration (UCLA-Triangle Method)

Net Radiation (250x250m, Daily)

Shortwave Radiation
- **MOD03** (1x1km)
Solar Zenith Angle, Geolocation (Lat,Lon)
- **MOD04** (10x10km)
Aerosol Optical Depth, Angstrom Exponent
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- **MOD06** (1x1km)
Cloud Fraction, Cloud Optical Thickness, Surface Temp

Bisht and Bras, 2010; Kim and Hogue, 2010

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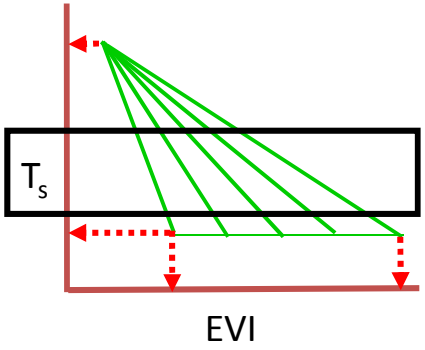
Evaporative Fraction
- **MOD13Q1** (EVI)
- **MOD11** (LST)



→ **ET** (250x250m, Daily)

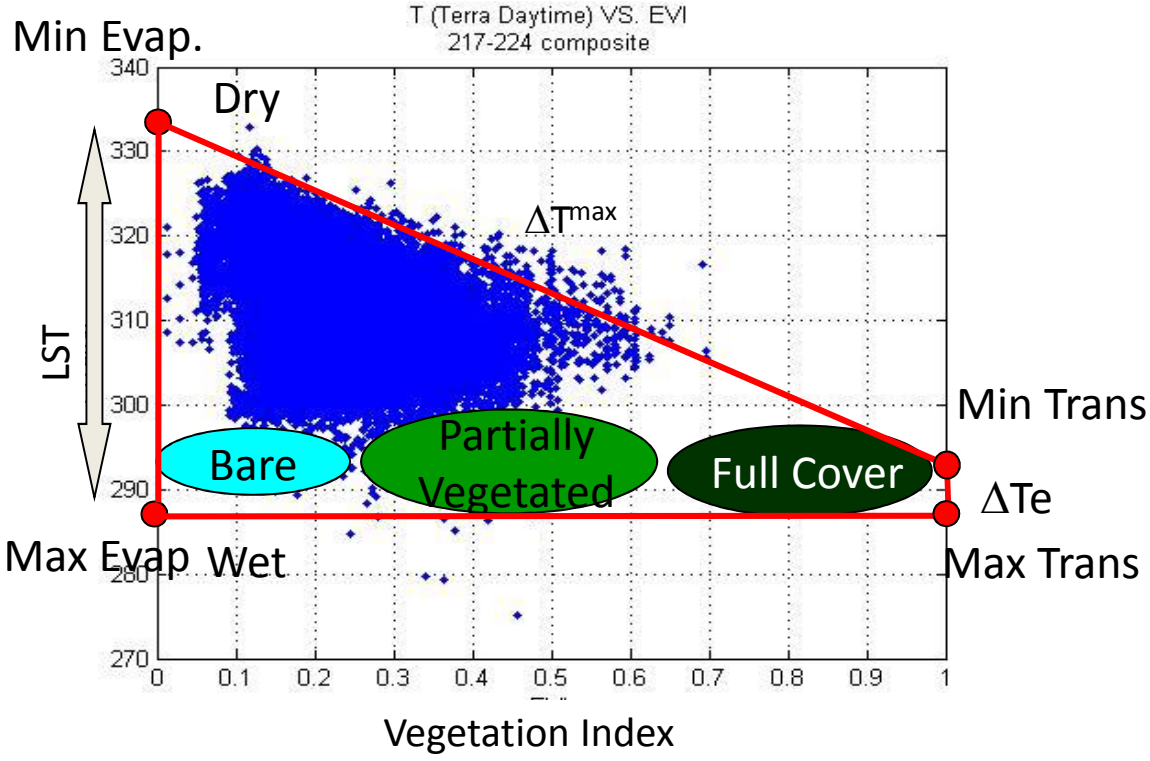
$$ET = EF \times (Rn - G)$$

Kim and Hogue, 2012; Jiang and Islam, 2003

Evapotranspiration (UCLA-Triangle Model)

- MODIS ET estimation using VI-LST Triangle Model

(Gillies and Carlson, 1995)

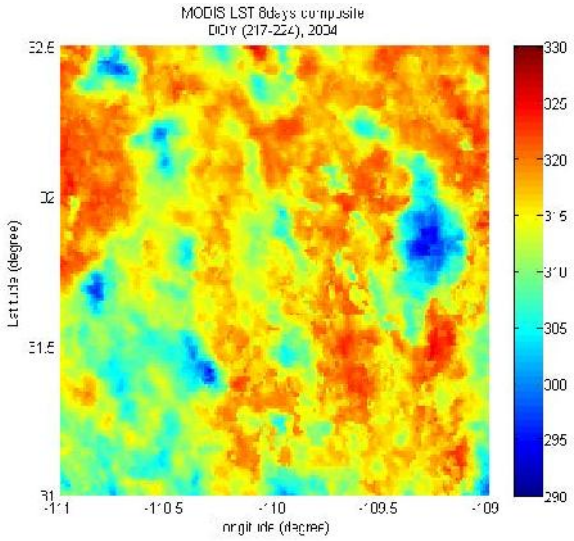


$$EF = \frac{ET}{Rn - G} = 1 - \frac{\rho C_p}{Rn - G}\frac{1}{r_a}\Delta T$$

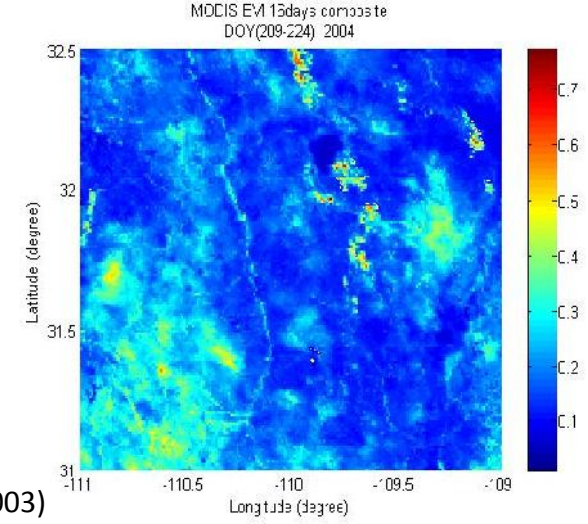
$$EF = 1 - \frac{(1 - EVI^*)\Delta T}{(1 - EVI^*)\Delta T_i^{max} + EVI^* \Delta T_e}$$

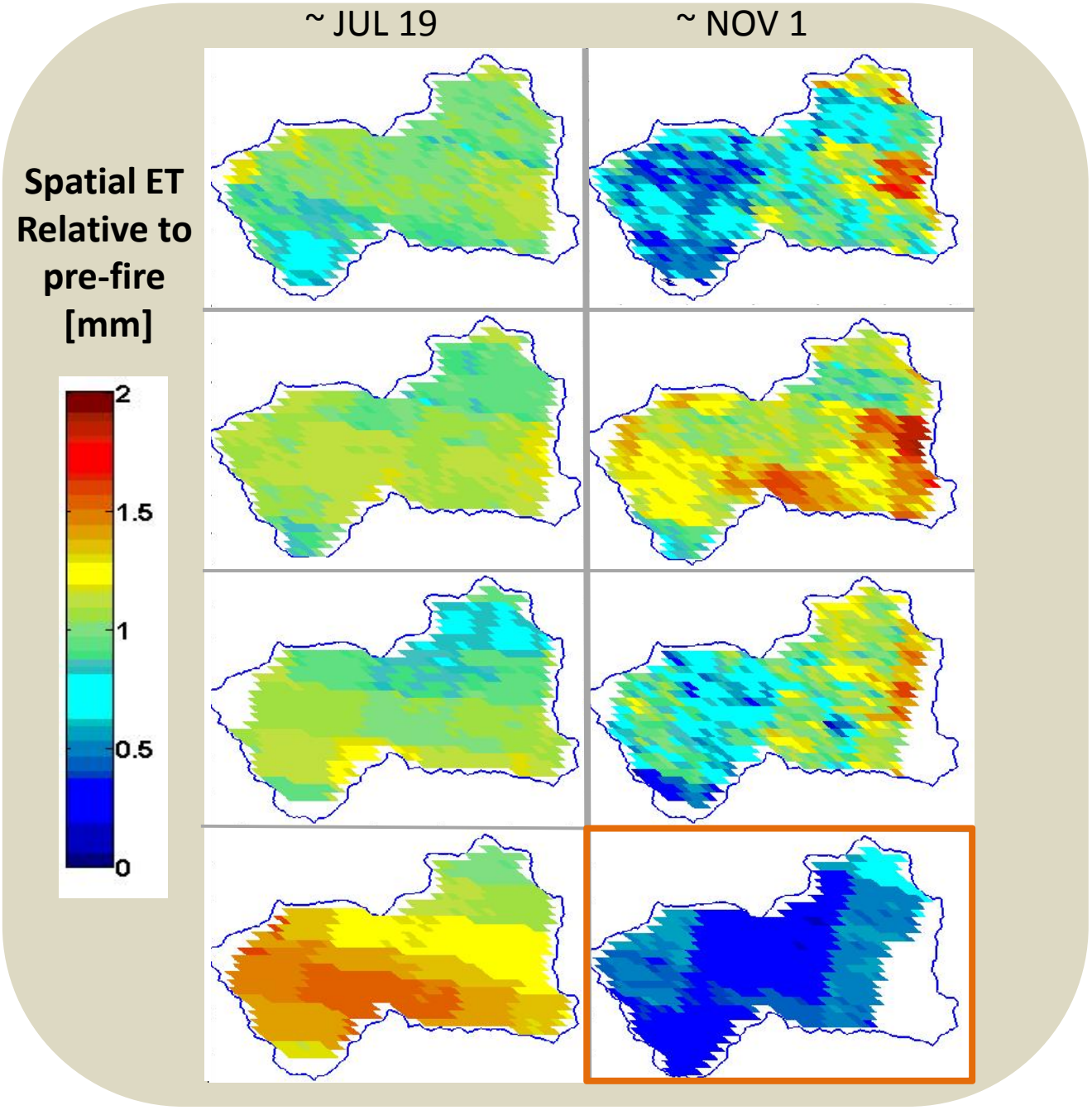
(Jiang and Islam, 2003)

MODIS (MOD11) LST -



MODIS (MOD13) VI (NDVI or EVI) -





2006
Jul: 4.7 mm
Nov: 1.2 mm

2007
Jul: 5.0 mm
Nov: 1.8 mm

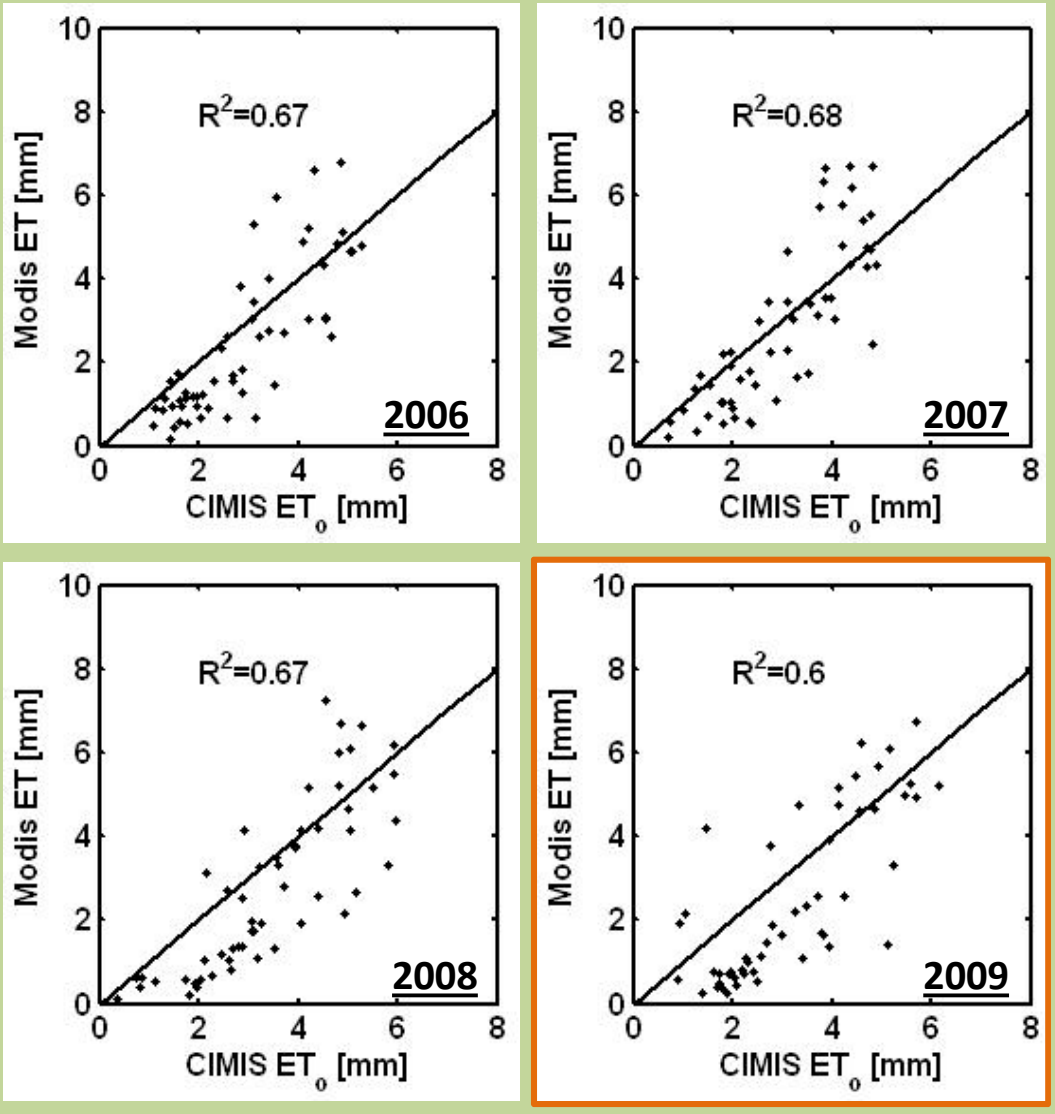
2008
Jul: 4.8 mm
Nov: 1.4 mm

2009
Jul: 6.2 mm
Nov: 1.1 mm

*** 663 pixels**

MODIS ET Validation – comparison to CIMIS ETo

Weekly Comparison



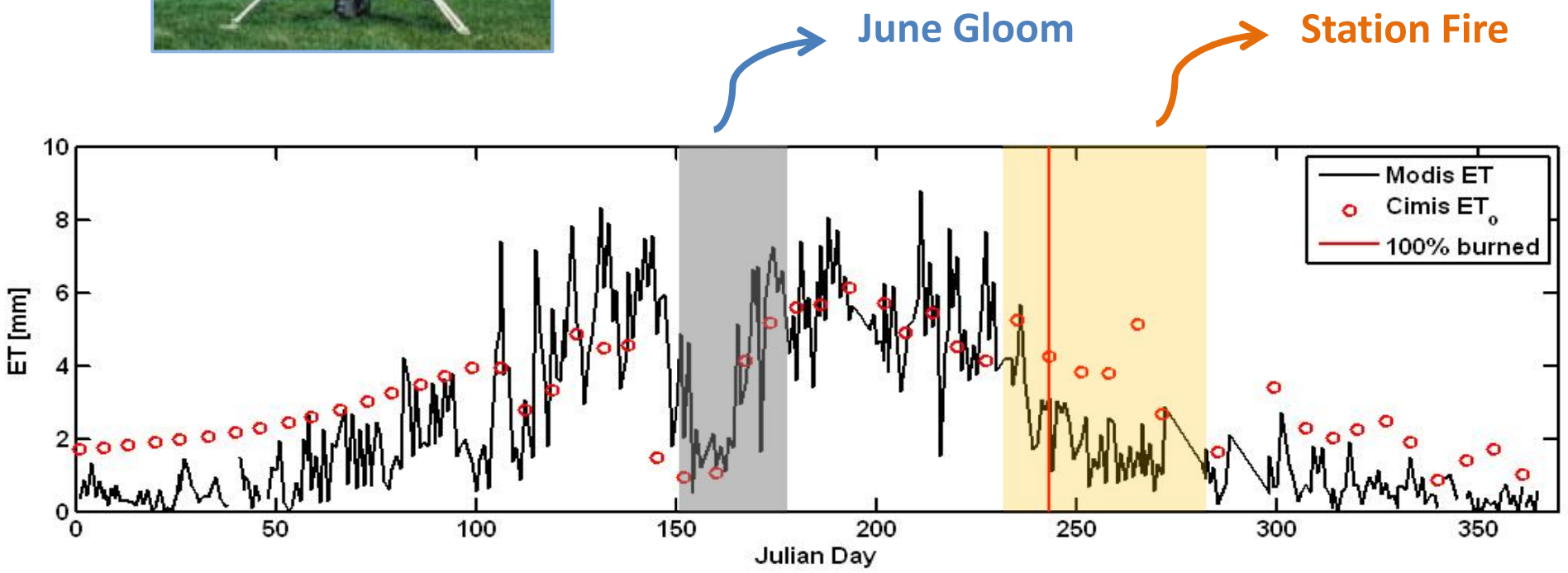
Annual Totals

Year	CIMIS Eto [mm]	MOD ET [mm]
2006	1095	917
2007	1111	1074
2008	1307	1061
2009	1157	894

- 2009 - Station Fire
- CIMIS ETo has a maximum ~6 mm

2009 MODIS Daily ET vs. Weekly CIMIS ETo

Glendale CIMIS ET_o (reference ET) measurements over well-watered, maintained grass (~potential)



Higher resolution ET needed for burn areas

Concluding Remarks

- **Initial work of the 2003 Old Fire shows post-fire hydrology is controlled primarily by EVI, slope aspect, burn severity**
- **Climate has shorter-term impacts**
- **Remote sensing ET over Arroyo Seco captures seasonal trends**
- **Developed product provides critical spatial and temporal information**

Future work

- **Higher spatial resolution (MODIS+Landsat product) integrated *(daily, 30m)***
- **Produce soil moisture product for burned systems (AMSR-MODIS; Kim and Hogue, 2012)**
- **Develop short and long-term water balance for burned areas**
- **Incorporate key variables controlling recovery in multi-variable model to predict daily discharge in ungauged systems**

Questions?

Acknowledgments

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